Chelan

Located at Mile Post 8.22 on State Route 971, above Lake Chelan, this 630 foot long by 70 feet high, north-facing slope has been a chronic source of surface erosion and ditch maintenance needs.

Figure 1. SR 971, Mile Post 8.22 vicinity, June 1999

Geology and Soils

Soils on site are composed of glacial deposits and volcanic ash overlying granitic bedrock. The glacial deposits are composed of sand, gravel, cobbles, and boulders. The weathering of the granite bedrock into rocks, fragments, and mineral components is called grus; in particular the feldspar minerals weather rapidly to a fine or "ashy" size. There is evidence, as seen in Figure 2, of chronic surface erosion with rilling and associated accumulated debris in the ditch line.

Climate and Moisture

During the June 1999 site visit, the soil was moist. This is a north-facing slope which receives no direct sunshine from fall through spring.

This area receives an average of 10.9 inches of precipitation per year. Snow depth in January is approximately five inches. Average maximum temperature is 85ºF which occurs during the month of July. Average minimum temperature is 22.2ºF in January. Further climate data can be found at:

http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wachel

Existing Vegetation

There was sparse existing vegetation on the slope face consisting of a bitterbrush (Purshia tridentata) and ponderosa pine (Pinus ponderosa) community and one willow (salix exigua). See Appendix G. This vegetation was located on portions of the slope that were at an angle of repose of 1.5(V):1(H). Where the slope was steeper, there was no vegetation growing.

The slope above the vertical lip has a ponderosa pine community established. The vegetation, especially the mature trees, growing on the edge are at risk because of continual erosion.

Figure 2. Vegetation community on stable soils

Opportunities and Constraints

This site had some moisture present combined with a favorable slope aspect, high public visibility, and a large bank of volunteer plants on the slope above. The adjacent landowners were willing to grant WSDOT a construction easement allowing an excavator to flatten the slope angle and increase stabilization of the site.

The team's engineering geologist said that traditionally, she would not have recommended additional work beyond reducing slope steepness. A flatter slope angle would help reduce surface erosion and provide favorable ground to establish vegetation. As with traditional engineering methods, soil bioengineering also requires "re-working" the slope profile, but also incorporates vegetative treatments to accelerate site recovery while providing a more permanent solution to the erosion problem.

The constraints were the large amount of excavation necessary to lay the slope back to 1 ½ :1 and the small amount of moisture in the soil during the summer. Because of the relatively dry conditions, traditional soil bioengineering techniques were altered to fit the dry site conditions.

Design Solution

After consultations with fellow scientists and lumber experts, the PI's solution was to use cedar bender board fencing. The consensus was that the slope would benefit from terracing, but traditional soil bioengineering plant species, such as willow, would not be appropriate for these site conditions. As a result, cedar bender board fencing was used as an alternative to willow walls to reduce the length and steepness of the slope and to create stable planting platforms for easier establishment of native (dry climate) vegetation.

The PI's original bender board fencing detail and specifications are found in Figure 4:

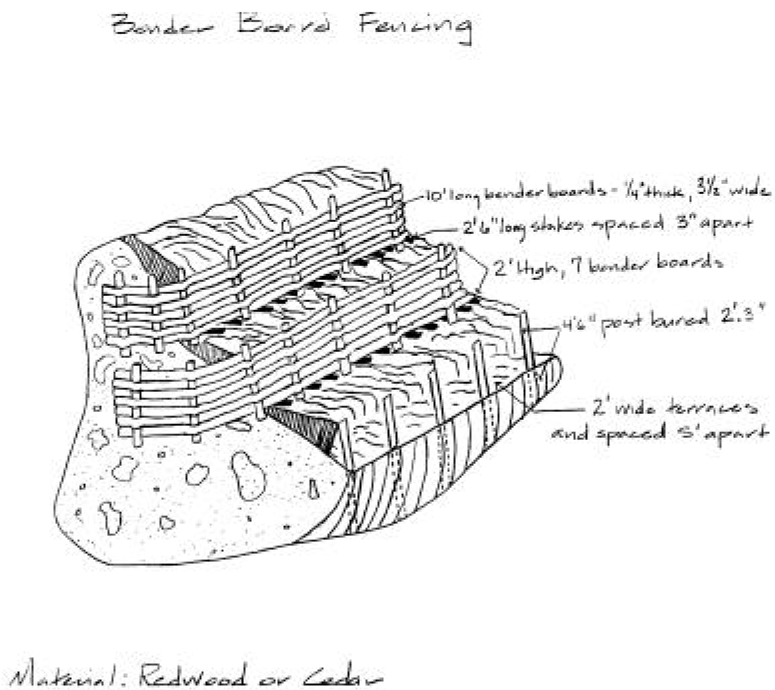

Figure 3. Bender board fencing

Bender board Fence Specifications

Redwood or cedar bender board fencing is essentially a fence supported on a short layer of shrub or tree stems. Specifically, it is a short retaining wall built of redwood or cedar bender fencing with a stem layered base.

<u>Tools needed</u>:

Hand pruners and clippers

Pulaski or hazel hoe

McLeod rake

Deadblow or rubber hammer

Pickaxe

Wood stakes

Stem Layered Base

Begin project at base of treatment area. Excavate 24" deep terrace along slope contour and for full width of treatment area. The back of the terrace should be dug with an approximate 70 degree angle. To allow ample planting platforms, space terraces about 5' apart.

Lay 2'6" long stems and 2'6" long wood stakes (50/50 mix) 2 inches apart and for full length of terrace. Diameter can range from 1/2" to 2". Approximately 6" will extend beyond slope face. Every 1’, place plant material (plugs) within the terrace.

Bender Board Fencing Construction

Drive supporting 4'6" (2' x 2') long stakes 2'3" into ground, vertically, and spaced 2' apart.

Weave 10' long bender boards through these stakes until the wall reaches a height of 2'. Once complete the bender board fence wall should be at a 15 degree angle to the slope. Once the wall frame is constructed, carefully rake enough soil into the terrace to cover the stem layered base.

Stand in terrace and begin excavation of second row. This process will allow soil from second trench to cover first bender board fencing row.

A goal should be to construct a 2:1 slope, or flatter, between the top of the bender board fence wall and the bottom of the one above.

Move upslope to next terrace alignment and repeat process.

Plant trees and shrubs on terraces. Species mix has been selected by PI, RA, and WSDOT Landscape Architects. Location of installation will be determined by RA and Landscape Architect(s) at WSDOT. PI will review to make sure placement meets slope stability objectives.

Construction

- ?? North Central Region (NCR) Maintenance and the Environmental Office surveyed, staked, and created a topographic map of the site.
- ?? NCR Real Estate Services contacted the landowners and obtained a construction easement for work through April 30, 2000.
- ?? NCR Maintenance opted to use a contractor to excavate the vertical lip of the slope. The contractor removed approximately 11,000 cubic yards of material.
- ?? NCR Maintenance provided traffic control during the 5.5 days of excavation.

Problems and Solutions During Construction

The contractor began working on Monday, November 1, 1999. His crew removed approximately 14 trees near the right of way line, and then attempted to remove the vertical lip of the slope from above. Because of the large amount of volcanic ash and glacial materials, the top soil layer was soft and difficult to excavate. As a result, the front-end loader left deep track marks and began slipping near the slope edge and had to be pulled out by an excavator. The soil disturbance on their property upset the landowners. As a result, the contractor removed his machinery and began working from the base of the slope with an excavator.

Soil below the soft top layer was composed of compacted glacial materials. These compacted materials were hard and required the contractor to use a bucket with teeth to scrape at the “rock-like” material. These conditions lengthened the excavation time beyond the anticipated three to four days.

The Washington Conservation Crew (WCC, hereinafter referred to as “the Crew”) arrived on Thursday afternoon, November 4, 1999 while the heavy equipment contractor was still working. However, the contractor had finished excavation on the west end of the site by that time. The Crew spent Thursday setting up their materials. The Research Assistant (RA) used a laser level to stake level terraces. Beginning from the west, the Crew began digging out the terraces with great difficulty. In addition, the Crew could not start from the bottom of the slope because the excavator was working there. Therefore, they began with one of the middle terraces working from the west end of the site. Because of the hardness of the soil, terrace construction took much more time than anticipated. Once the soil was broken up however, it became a fine powder mixed with sand and rounded rocks. This mix of soil materials made walking on the slope difficult.

As the RA and the Crew began trying to construct the bender board fencing as designed, they discovered they could not get the specified wooden stakes into the ground. The RA decided to try ½ inch diameter rebar and to use the wood stakes as the brush layer base. In addition, the bender board material was much thinner and weaker than anticipated. This necessitated a change in the design. Plant plugs had been heeled-in within the right of way and were now frozen. To plant the plugs, the Crew chief thawed the plugs and set them between the brush layer every 3 feet where they froze again.

When the WSDOT Landscape Designer, hereinafter referred to as the Landscape Designer, arrived on Sunday, November 7, 1999 approximately 110 feet of bender board terrace 7 boards high had been constructed and approximately two-thirds of the slope had been excavated back to 1 ½ (H):1 (V).

On Monday, the heavy equipment contractor returned to finish the excavation on the eastern end of the site and the Crew continued constructing the level terrace. The Landscape Designer had the Crew leave the terrace and had the excavator operator backfill the terrace with excavated material. The operator was very careful and worked to shake out boulders before he placed the soil behind the bender board fencing. Immediately after backfilling, the terrace looked good. However, three hours later, sections of the terrace had warped out of alignment in a slow deformation. The Landscape Designer had the Crew remove the soil down to a depth of less than 1 foot in an attempt to halt the bending of the rebar and the breaking of the bender board material. The Crew also began repairing the damaged area, including the landowner’s property. Repair work included raking, seeding, and planting.

Planted on the landowner's property were:

Service berry (Amelanchier alnifolia)	10
Snow berry (Symphoricarpos albus)	20
Blue Elderberry (Sambucus cerulea)	5
Mock Orange (Philidelphus lewisii)	5
Ponderosa Pine (Pinus ponderosa)	50
Squaw currant (Ribes cereum)	10
Native seed mix	10lbs

Even after attempting repairs on the bender board fence, the Crew could still feel the brush layer on the base of the terrace moving and hear bender boards cracking. The Crew leader did not feel that ½ inch rebar had enough strength to be driven into the soil without bending. The Landscape Designer consulted with the PI by phone and a decision was made to halt Crew work on the site at the end of the day on Monday, pending a site visit by the PI and WSDOT technical advisors. The Landscape Designer was also concerned by the large amount of rebar going into a soil bioengineering project.

The Contractor completed excavation of the slope face by noon on Tuesday, November 9th.

Further hand construction was delayed until after the first week in December when the PI, the OSC Roadside and Site Development Manager, and Department of Ecology Soil Scientist Mark Cullington could examine the slope conditions. They made the on site decision to continue using rebar to reinforce the terraces and to adjust bender board structures from two feet to a one foot height (3 boards instead of 6).

Construction resumed with a different Crew in mid December. The RA and the Crew made an additional decision to discontinue weaving the bender board through the rebar because the bender board was breaking. The poor quality bender board was thin and had many knots. In addition, the gaps in the fencing, created by the weave, allowed soil to erode out from the bender board face. Instead, they had the soil hold the boards against the rebar. This adjustment also held the soil in place.

Biosolid Application

In addition to reshaping the slope to 1 ½ to 1 and constructing bender board fencing terraces, the PI recommended biosolid application to increase soil moisture holding capacity and improve soil nutrient levels. The objective was to accelerate native plant establishment and provide long-term site recovery.

Mark Cullington prescribed a Class-A-biosolid and fir-compost mixture for the slope to provide the soil and native plants with an ideal carbon to nitrogen ratio. Class A biosolids undergo an additional process to kill pathogens. The biosolid industry is highly regulated. Cullington developed the application formula in his Master's thesis in Soil Science at the University of Washington. In addition Cullington states that a high carbon to nitrogen ratio (C:N) suppresses weeds. The addition of Class A biosolids improves the moisture holding capacity of mineral soil and is especially beneficial in arid climates. (Cullington's worksheet is found as Appendix F).

GroCo compost was blown onto two-thirds of the slope on December 22, 1999. The prescription was for a very fine layer, of approximately 3/4 inch, to cover the slope. Due to the high moisture content of the compost and weight restrictions, the contractor could not haul all of the compost that he had anticipated. This high moisture content also caused the blower to lay on a thicker cover (but less than 2") and, therefore, ran out of compost before covering the entire site. Because of cost and distance, the team decided to use the uncovered area as a control.

The prescription also required incorporation of the biosolids into the soil immediately upon application. This was not done until the terraces were constructed, and only in the terrace itself. Due to the cemented soil conditions of the substrate, the RA considered that it would add several weeks to the workload of the crew. Where soils were pliable, the crew did incorporate the soil amendments and in the terraces, where the crew chipped off mineral soil with pickaxes to fill the terraces, the amendment was also incorporated.

The Crew stated there was a large difference in the ability to construct the terraces and pound in the rebar after the application of the compost. The soil was much easier to work with after the compost application.

Terrace Construction

The Crew continued to construct the terraces and bender board fencing until the ground froze too deeply to work. They quit for the season on January 13,1999. The photo below shows the site at that time.

Figure 4. End of season - January 13, 2000

The Landscape Designer checked the site on March 15, 2000 to determine if the soil had thawed and to check for disturbance to the site during winter. Without snow mixed into the soil, the soil had settled, allowing some of the boards to fall back onto the terrace. This can be seen in Figure 6. With the addition of water, areas on the control section had liquefied and moved down slope. However, where compost had been applied, there was no visible movement of soil.

Figure 5. Status before Spring construction - March 15, 2000

Work resumed on April 6, 2000 with the original crew. This crew worked an 8-day shift. The Crew completed the planting and constructing of the 1875 feet of terraces by April 13, 2000.

Planted within WSDOT right of way:

Service berry (Amelanchier alnifolia)	155
Snow berry (Symphoricarpos albus)	155
Blue Elderberry (Sambucus cerulea)	350
Mock Orange (Philadelphus lewisii)	160
Basin Big Sage (Purshia tridentata)	450
Antelope Bitterbrush (Artemis tridentata tridentata)	450
Rubber Rabbit Brush (Chrysothamnus nauseosus)	450
Ponderosa Pine (Pinus ponderosa)	950
Squaw currant (Ribes cereum)	190
Antelope Bitterbrush (Purshia tridenta)	200

The RA returned to the site during the last week in April to clean up unused rebar, bender board, and other remaining construction materials. Construction was complete by April 28, 2000.

By the end of June the bender board appeared to have stabilized the surface erosion and grass was growing on all terraces, however, where the composted biosolids were applied, The annual rye was thicker, greener and withstanding drought conditions better than the control section without compost as seen in the photo below. The predominant vegetation on the control section was Idaho fescue.

2000 Monitoring Results

- ?? Trend is improving.
- ?? Slight evidence of continued surface erosion in unvegetated areas.
- ?? Site is showing 43% vegetative cover.
- ?? Survivability of woody vegetation planted as the brush layer base of each terrace varies with position on slope. Possibly related to soil moisture availability, thawing and refreezing, or installation date. Plants installed at the base of the structures:
    - o Terraces 1-5 showed 40% survival.
    - o Terrace 6 showed 75% survival.
    - o Terrace 7 showed 70% survival.
    - o Terrace 8 showed 75% survival.
    - o Terrace 9 showed 60% survival.
    - o Terrace 10 showed 80% survival.
- ?? Native woody vegetation survivability planted on top of the terraces:
    - o Uniform groundcover of native plants – 15% overall.
    - o Uniform survival of native plants – 70% overall.
    - o Uniform survival of native plants (Ponderosa Pine sp.) – 90% overall.
    - o No survival difference in first 6 months in woody vegetation between areas with/without compost.
    - o Marked increase in vigor in horizontally planted vegetation with compost added to area.

As of October 2000, trees planted on the landowners' property were green, as seen from below, and grass and trees were growing in the soil disturbed by the bobcat.

Figure 6. Grass communities differ with biosolids

Long-term monitoring will allow WSDOT to determine long term slope stability and to further understand the relationship between native plants, native soil, and biosolids. The status of this site in July 2000 is shown in Figure 8.

Figure 8. Chelan, July 20, 2000